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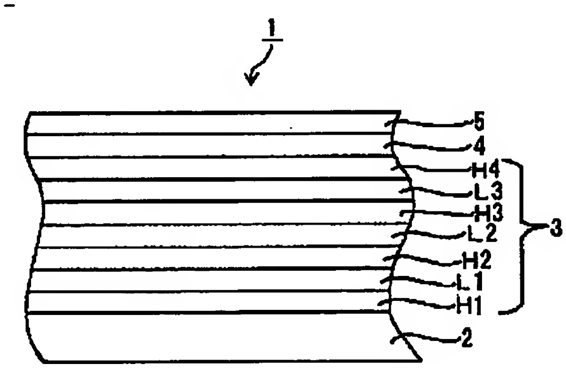
(54) [Name of Invention] Projection Screen

(57) [Summary]
[Issues] To provide a clear image without being affected by the brightness of the projection environment.
[Resolution] Projection screens related to this invention are projection screens for displaying images by projecting narrow-band primary color wavelength region light characterized by having high reflective properties for the aforementioned narrow-band primary color wavelength region light, and have a thin optical film (3) on an insulator for support (2) that has high permeation characteristics for at least visible wavelength region light other than the particular wavelength region light. The thin optical film (3) fulfills the role of a band region filter for projection screens that are related to this invention and are constructed as above. Specifically, the aforementioned thin optical film (3), by reflecting narrow-band primary color wavelength region light and filtering most light of other wavelengths, functions as a narrow-band primary color wavelength region filter that acts as a separator for these types of light.



[Scope of Patent Claims]

[Claim 1] Projection screens for displaying images by projecting narrow-band primary color wavelength region light, that are characterized by having high reflective properties for the aforementioned narrow-band primary color wavelength region light, and possess a thin optical film that has high permeation characteristics, at least for visible wavelength region light other than the light for the particular wavelength region.

[Claim 2] Projection screens in Claim 1 that are characterized by the aforementioned thin optical film being composed of a dielectric multilayer film made up of alternating layers of high refractive index and low refractive index, and for which the optical thickness *nd* of each layer of the applicable dielectric multilayer film satisfies the conditions of Formula (1) below, with regards to each wavelength λ of the aforementioned narrow-band primary color wavelength region light, when the refractive index of each layer of the applicable dielectric multilayer film is assumed to be *n*, and the film thickness of each layer is assumed to be *d*.

$$nd=\lambda\,(\alpha\pm 1/4) \qquad (\alpha \text{ is a natural number}) \ldots (1)$$

[Claim 3] Projection screens in Claim 2 that are characterized by the optical thickness *nd* of each layer of the aforementioned dielectric multilayer film being within the range of 1.462μm~1.467μm.

[Claim 4] Projection screens in Claim 2 characterized by the aforementioned dielectric multilayer film having the incidence side for the aforementioned narrow-band primary color wavelength region light and the outermost layer of the opposing side being high refractive index layers.

[Claim 5] Projection screens in Claim 2 characterized by the aforementioned high refractive index layer being composed of cerium oxide, and the aforementioned low refractive index layer being composed of magnesium fluorine.

[Claim 6] Projection screens in Claim 2 characterized by the aforementioned high refractive index layer being composed of zirconium oxide, and the aforementioned low refractive index layer composed of magnesium fluorine.

[Claim 7] Projection screens in Claim 2 characterized by the aforementioned high refractive index layer being composed of zinc sulfide, and the aforementioned low refractive index layer being composed of magnesium fluorine.

[Claim 8] Projection screens in Claim 2 characterized by the aforementioned high refractive index layer being composed of titanium oxide, and the aforementioned low refractive index layer being composed of magnesium fluorine.

[Claim 9] Projection screens in Claim 1 characterized by the possession of a light absorption layer that absorbs light transmitted through the aforementioned thin optical film.

[Claim 10] Projection screens in Claim 9 characterized by the aforementioned light absorption layer containing blacking.

[Claim 11] Projection screens in Claim 10 characterized by the aforementioned light absorption layer being an insulator for support formed containing blacking.

[Claim 12] Projection screens in Claim 1 characterized by the aforementioned narrow-band primary color wavelength region light that is laser light.

[Claim 13] Projection screens in Claim 12 characterized by the aforementioned narrow-band primary color wavelength region light being wavelength 457nm blue laser light, wavelength 532nm green laser light, and wavelength 642nm red laser light.

[Claim 14] Projection screens in Claim 1 characterized by having a light diffusion layer on the outermost layer of the aforementioned thin optical film, or as an interlayer of the thin optical film.

[Claim 15] Projection screens in Claim 14 characterized by the aforementioned light diffusion layer having high scattering properties with regards to the aforementioned narrow-band primary color wavelength region light.

[Claim 16] Projection screens in Claim 14 characterized by the aforementioned light diffusion layer having multiple layers built into it.

[Claim 17] Projection screens in Claim 14 characterized by the aforementioned light diffusion layer containing silver particles, copper particles, gold particles or nickel particles.

[Claim 18] Projection screens for displaying images by projecting light that has the necessary wavelength regions, has high reflective properties for light that has the aforementioned necessary wavelength regions, and possesses a thin optical film that has high permeation characteristics for at least visible wavelength region light other than the light that has the applicable wavelength regions.

[Claim 19] Projection screens in Claim 1 that are characterized by the aforementioned thin optical film being composed of a dielectric multilayer film made up of alternating layers of high refractive index and low refractive index, and for which the optical thickness *nd* of each layer of the applicable dielectric multilayer film satisfies the conditions of Formula (2) below, with regards mainly to the wavelength λp of light that has the aforementioned wavelength region, when the refractive index of each layer of the applicable dielectric multilayer film is assumed to be *n*, and the film thickness of each layer is assumed to be *d*.

$$nd=\lambda p\,(\alpha\pm 1/4) \qquad (\alpha \text{ is a natural number}) \ldots (2)$$

[Claim 20] Projection screens in Claim 19 characterized by the optical thickness *nd* of each layer of the aforementioned dielectric multilayer film being within the range of 1.462~1.467μm.

[Claim 21] Projection screens in Claim 19 characterized by the aforementioned dielectric multilayer film having the incidence side for light that has the aforementioned wavelength region and the outermost layer of the opposing side being high refractive index layers.

[Claim 22] Projection screens in Claim 19 characterized by the aforementioned high refractive index layer being composed of cerium oxide, zirconium oxide, zinc sulfide, titanium oxide or some combination thereof, and the aforementioned low refractive index layer being composed of magnesium fluorine.

[Claim 23] Projection screens in Claim 18 characterized by the possession of a light absorption layer that absorbs light transmitted through the aforementioned thin optical film.

[Claim 24] Projection screens in Claim 23 characterized by the aforementioned light absorption layer containing blacking.

[Claim 25] Projection screens in Claim 24 characterized by the aforementioned light absorption layer being an insulator for support formed containing blacking.

[Claim 26] Projection screens in Claim 18 characterized by the aforementioned wavelength region light being light produced by individual light emitting diodes.

[Claim 27] Projection screens in Claim 18 characterized by the possession of single or multiple light diffusion layers as the outermost layers of the aforementioned thin optical film or as interlayers of the thin optical film.

[Claim 28] Projection screens in Claim 27 characterized by the aforementioned light diffusion layer containing silver particles, copper particles, gold particles or nickel particles.

[Detailed Explanation of Invention]

[0001]

[Technical Field to Which Invention Belongs] This invention applies to projection screens, specifically, projection screens recognized as having good projected images due to projector light even under bright lighting conditions.

[0002]

[Conventional Technology] In recent years, presenters have come to make wide use of overhead and slide projectors as ways of presenting data during meetings. In addition, even in general households, video projectors and animated film projectors that use liquid crystals are becoming popular. The projection method of these projectors is to create light images by modulating the light produced by a light source through such means, for example, as a permeable liquid crystal panel, and then to project these light images onto a screen by directing this image light through an optical system such as a lens.

[0003] An example is a front projector that can form a color image on a screen that is equipped with an illuminated optical system that separates light rays emitted by a light source into the individual colors of red (R), green (G), and blue (B) and unites them along a fixed optical path; a liquid crystal panel (light bulb) that individually modulates the light for each of the colors RGB separated by the illuminated optical system; and a light photosynthesizing component that synthesizes the light flux of each of the RGB color light modulated by the liquid crystal panel; and then produces an enlarged projection on a screen of color images synthesized by the photosynthesizing component by a projection lens

[0004] Furthermore, in recent times, projector devices have been under development that spatially modulate the light flux for each color RGB that use a narrow-band primary color light source as the light source, and employ a grating light valve (GLV) instead of a liquid crystal panel.

[0005]

[Issues Invention Will Attempt to Solve] On one hand, although projection screens are used in order to obtain projection images with projectors such as those mentioned above, when these screens are divided into general categories, there are permeable types where the projected light is emitted from the rear surface of the screen, and then viewed off of the screen's front surface, and reflecting types where the projected light is emitted from the front side of the screen and then the reflected light is viewed on a screen for the corresponding projected light. Regardless of which type, it is important that bright and high-contrast images are obtained in order to realize screens with good visibility. However, front projectors such as those described above differ depending on whether they are self-illuminating or rear projectors, and there are problems, such as the inability to reduce the reflection of outside light using ND filters, and difficulties in raising the contrast of bright spots on the screen.

[0006] In particular, with the projection method of projectors described above, because the projected light that processes the images is reflected by the screen, the image contrast is largely conditioned by the surrounding brightness, and even if the reflectance of the screen is simply raised, since the reflectance of outside light will rise without turning into only projected light, the recognition rate of the image will decrease. Accordingly, in cases where the projection environment is bright, it is difficult to obtain clear images.

[0007] At this point, this invention is the product of lessons taken from the past circumstances described above, with the purpose of this invention being to provide clear images without any effects from the brightness of the projection environment.

[0008]

[Measures to Resolve Issues] Projection screens related to this invention that are meant to achieve the goals described above are projection screens for displaying images by projecting narrow-band primary color wavelength region light that are characterized by having high reflective properties for narrow-band primary color wavelength region light and possess a thin optical film that has high permeation characteristics at least for visible wavelength region light other than the light for the particular wavelength region.

[0009] The optical thin film fulfills the role of a so-called narrow-band filter for screens used for projection related to this invention and constructed as in the above. In particular, the aforementioned thin optical film, by reflecting narrow-band primary color wavelength region light and filtering most light of other wavelengths, functions as a narrow-band primary color wavelength region filter that acts as a separator for these types of light.

[0010] Most narrow-band primary color wavelength region light is reflected by this type of projection screen through the use of this thin optical film. With regards to this, in cases when outside light incidences the screen, for example, most of it penetrates the projection screen, and is not reflected.

[0011] Accordingly, it is possible to selectively reflect narrow-band primary color wavelength light the with projection screens related to this invention, and it is possible to relatively control the reflection of outside light in comparison to conventional screens. As a result, the reflection of outside light is effectively reduced together with control of the drop in contrast of the image formed on the projection screen, and it is possible to obtain a bright image. Accordingly, even in cases where the projection environment is bright for this projection screen, it is possible to obtain a clear image, and further possible to obtain a clear image without any effect from the brightness of the projection environment.

[0012] In order to obtain functions such as those detailed above, it is important to design the thin optical film. For example, when a dielectric multilayer film made up of alternating layers of high refractive index and low refractive index is used as the thin optical film, and the refractive index of each layer is assumed to be n, and the film thickness of each layer is assumed to be d, then it is possible to obtain effects such as those described above by making designs for which the optical thickness nd satisfies the conditions of formula (3) below with regards to the wavelength λ of each of the lights emitted by the aforementioned narrow-band primary color light source.

[0013]

$$nd=\lambda\ (\alpha\pm 1/4) \qquad (\alpha \text{ is a natural number}) \ldots (3)$$

[0014] At this point, a band is formed that reflects the narrow-band primary color wavelength region light towards the thin optical film, in cases where the thin optical film is designed so that it satisfies the conditions of the aforementioned formula (3) with regards to all primary color wavelengths. As a result, it demonstrates high reflective properties for narrow-band primary color wavelength region light.

[0015] For example, in cases where a combination of wavelength 457nm blue laser light, wavelength 532nm green laser light, and wavelength 642nm red laser light is used as the narrow-band primary color wavelength region light, designs are possible which satisfy the conditions of the aforementioned formula (3) with regards to these primary color wavelengths, and a thin optical film that functions as a filter for the aforementioned bands is realized.

[0016] Also effective for projection screens related to this invention is for them to possess a light diffusion layer on the outermost layer of the thin optical film, or as an interlayer of the thin optical film, in addition to the thin optical film functioning as a band filter as mentioned above. The light diffusion layer is for obtaining diffuse light by diffusing the light reflected by the thin optical film. In cases where there is no light diffusion layer, the viewer will come to see only the reflected specula elements as reflected light from the projection screen. With only the reflected specula elements, there are disadvantages for the viewer, such as limiting their field of vision. If a light diffusion layer is put in place to counteract this, then the viewer will come to see diffuse light, greatly improving the characteristics of the field of vision, and making it possible to visually confirm a natural image.

[0017] In addition, projection screens outside of this invention are ones that display images by projecting light that has a fixed wavelength region, and are characterized by having high reflective properties for light that has the aforementioned fixed wavelength regions, and possesses a thin optical film that has high reflective properties at least for visible wavelength region light other than the light for the particular wavelength region.

[0018] Although it is possible to use narrow-band primary color wavelength region light, as stated before, as the light source for projecting images on a projection screen, it is also possible to make use of a light emitting element, such as a light emitting diode for example, as light source that has a comparatively wide spread in terms of emission wavelength. In addition, it is acceptable even if these wavelengths are ones that are divided within the visible region, like primary colors, by combining a light source that has some spread across the band with a filter, nonlinear optical elements, or nonlinear thin optical film. It is acceptable even if, with regards to the light that has the aforementioned fixed wavelength region, it is a primary color wavelength region light for which, the band, by comparison, combines wide emissions, even while at its peak, like a light emitting diode. Even with this type of construction, the thin optical film performs effective reflection that focuses the wavelength region that emphasizes light with the fixed wavelength region. With this type of projection screen, the fixed wavelength region light favorably reflects the main wavelength components through the effect of the thin optical film. With regards to this, in cases where outside light incidences the screen, the greater part penetrates the projection screen, and most comes to not be reflected.

[0019]

[Implementation of Invention] Below, we will explain this invention while making reference to diagrams. Moreover, this invention is not limited solely to the entries below, but it is possible for there to be changes in its applicability within a range in which the substance of this invention does not deviate.

[0020] Projection screens related to this invention are projection screens for displaying images by projecting narrow-band primary color wavelength region light, that are characterized by having high reflective properties for narrow-band primary color wavelength region light, and possess a thin optical film on an insulator for support that has high reflective properties with regards to at least visible wavelength region light that is outside the particular wavelength region.

[0021] Fig. 1 shows a cutaway diagram of a screen for a front projector that is a projection screen constructed according to this invention. This projector screen (1) is a projector screen for showing diffraction grating-type projector images by using a grating light valve (GLV), and displaying images by projecting narrow-band primary color wavelength region light that is light emitted by a narrow-band primary color light source that is a diffraction grating-type projector. This projector screen is one that possesses a thin optical film (3) that is a dielectric multilayer film that functions as a band filter on the screen substrate (2), and which has a light diffusion layer (4) in place on the particular thin optical film (3), and furthermore has a protective film (5) formed on top of it.

[0022] At this point, the narrow-band primary color light source is not a light source for which the wavelength spread is several tens of nm like a light emitting diode (LED), but means a light source for which the wavelength spread is about several nm, and mainly refers to a laser light source. Since emission light from a narrow-band primary color light source is one for which the wavelength spread is very small, it is possible to form a clear image, in comparison to other types of light sources, by using a narrow-band primary color light source.

[0023] The screen substrate (2) is one that becomes an insulator for support for the projector screen (1), and can be formed from a polymer, such as polyethylene terephthalate (PET), polyethylene naphthalate (PEN), polyether sulfone (PES), or polyolefin (PO). In addition, the screen substrate (2), by containing blacking, etc., is formed with a black color. By assuming that the screen substrate (2) color is black, as in this case, the screen substrate itself functions as a light absorption layer, and it is possible prevent the reflection of the light that penetrates the thin optical film (3) in order for the screen substrate (2) to absorb the light that penetrates the thin optical film (3) as described later. In this manner, it becomes possible definitely to obtain narrow-band primary color wavelength region light as reflected light, as described later, and also possible to raise the black level and improve the contrast. In addition, instead of using the screen substrate (2), a construction which has blacking on the surface of the screen substrate (2) is acceptable, and in this case, the blacking functions as a light absorption layer and is able to raise the black level and improve the contrast without reflecting the light that penetrates the thin optical film (3).

[0024] The thin optical film (3) is composed of alternating layers of high refractive index layers H, that are of a dielectric optical film formed out of a high refractive index material, and low refractive index layers L, that are of a dielectric optical film formed out of a low refractive index material, and when it is assumed, for each layer of the dielectric multilayer film, that the refractive index of each layer of high refractive index layer H and low refractive index layer L is *n*, and that the film thickness of each layer is *d*, then the optical thickness *nd* of each dielectric thin film is constructed so that it satisfies the conditions of the formula (4) below, with regards to each wavelength λ for the narrow-band primary color wavelength region light that is light emitted from the narrow-band primary color light source.

[0025]

$$nd=\lambda\ (\alpha\pm 1/4) \qquad (\alpha \text{ is a natural number}) \ldots (4)$$

[0026] In particular, the thin optical film (3) is made up of alternating layers of high refractive index H and low refractive index L, for which the optical thickness *nd* of each layer is made to correspond to a fixed value. At this point, a range of 1.462μm~1.467μm is desirable for the optical thickness. Then, a reflecting band is formed for the thin optical film (3) that has high reflective properties with regards to narrow-band primary color wavelength region light that is light emitted from a narrow-band primary color light source at a wavelength position that satisfies these types of conditions. Through formation of this reflecting band, narrow-band primary color wavelength light, which is light emitted from a narrow-band primary color light source, is reflected without penetration by this thin optical film (3). In addition, the thin optical film (3) has high reflective properties with regards to the light for wavelength regions outside of this reflecting band. In particular, the thin optical film (3) selectively reflects narrow-band primary color wavelength light, and functions as a narrow-band primary color wavelength region filter that allows most of the light of wavelength regions other than this to penetrate.

[0027] Accordingly, although the projector screen (1) selectively reflects narrow-band primary color wavelength light that is light emitted from a narrow-band primary color light source through possession of this kind of thin optical film (3), it is possible to allow most of the light for wavelength regions outside of this to penetrate.

[0028] Due to this, with this projector screen (1), even if outside light momentarily gets into the projector screen (1), since light other than the narrow-band primary color wavelength light is mostly cut by being allowed to penetrate, it is possible to prevent problems such as drops in contrast caused by outside light or reflection of outside light.

[0029] In particular, since with this projector screen (1) it is possible to selectively reflect narrow-band primary color wavelength light, and relatively control the reflection of outside light in comparison to conventional screens, it is possible to effectively reduce the reflection of outside light together with being able to control the drop in contrast of images formed on the projector screen (1), and it is possible to obtain bright images. Accordingly, with this projector screen (1), clear images can be obtained even in cases where projection environments are bright, and it is possible to obtain clear images without being affected by the brightness of the projection environment.

[0030] In addition, based on the explanation given above, due to the multiplying effect of the thin optical film (3) described above, which drastically intensifies the wavelength characteristics of the light emitted from the narrow-band primary color light source for the projector, the effects of this invention are increased since it is possible to make the light almost entirely into light emitted from the projector. Then, a light source for which the wavelength spread is about several nm, a laser light, for example, is suitable.

[0031] In addition, in cases where the optical thickness of each layer of the dielectric multilayer film satisfies the conditions of the aforementioned formula (4) as described above, a reflecting band that has high refractive properties with regards to narrow-band primary color wavelength region light is formed, but is not limited to combinations of the three natural numbers α for which the optical thickness *nd* satisfies the conditions of the aforementioned formula (4) with regards to the optional primary color wavelength. With regards to combinations that satisfy these types of conditions, examples are combinations of wavelength 457nm blue laser light, wavelength 532nm green laser light, and wavelength 642nm red laser light. These wavelengths are wavelengths for light sources that are being used with diffraction grating-type projectors (11) that use GLV, and through this combination, when it is assumed that the optical thickness *nd* is 1.467μm, the optical thickness *nd* is a 3.25x abbreviation of the blue laser light, a 2.75x abbreviation of the green laser light, and a 2.25x abbreviation of the red laser light, and approximately satisfies the conditions of the aforementioned formula (4). In this manner, it is possible to obtain the effects described above through approximately satisfying the conditions of the aforementioned formula (4) without needing to match them exactly.

[0032] Furthermore, H1, H2, H3, and H4 in Fig. 1 are the individual high refractive index layers, and L1, L2, and L3 are the individual low refractive index layers.

[0033] With this projector screen (1), in order to realize the selective reflecting spectrum, although the thin optical film (3) is assumed to be made of alternating high refractive index layers H and low refractive index layers L as described above, the number of layers is not specifically limited, and it is possible to use the desired number of layers. By changing the number of layers, it is possible to adjust the width, etc. of the reflecting band. In addition, it is desirable for the dielectric multilayer film to be formed by an odd number of layers, with the outermost layers of the narrow-band primary color wavelength region light incidence side and the opposite side being high refractive index layers. Dielectric multilayer film, specifically, thin optical film (3), formed from odd layer dielectric thin film, in comparison to cases in which dielectric multilayer film is formed from even layer dielectric thin film, is one in which its function as a narrow-band primary color wavelength region filter is excellent.

[0034] Then, in terms of a definite layer count, a total of 7~11 layers of high refractive index layer H and low refractive index layer L are desirable. In cases where the number of layers is too few, there is a concern that it will not be possible to adequately demonstrate its functions as a narrow-band primary color wavelength region filter, and in cases where the number of

layers is too many, a lengthy time is required to manufacture the thin optical film. Accordingly, by constructing a thin optical film with the total number of high refractive index layers H and low refractive index layers L amounting to 7~11 layers, it is possible to construct an effective thin optical film (3) that adequately functions as a narrow-band primary color wavelength region filter.

[0035] The reflectance for a specific wavelength band is raised by increasing the number of accumulated layers with this thin optical film (3), and, in addition, in cases where the same number of layers is accumulated, the difference in the refractive index between the high refractive index layer H and low refractive index layer L is raised to a large degree. Based on this, it is desirable if the refractive index of the high refractive index layer H which forms the thin optical film (3) is as high as possible, more specifically preferable if it is over 2.1 or under 2.7. This is because, in cases where the refractivity of the high refractive index layer H is smaller than even 2.1, the necessity arises for a large number of layers in order to realize the fixed selected reflection spectrum, and, because thin optical film material for which the refractive index is greater than 2.7 does not exist in great numbers, and the allowance selected for material combinations for the high refractive index layer H is narrow. It is possible to construct a high refractive index layer H that has this kind of refractive index from high refractive index materials such as zinc sulfide (ZnS), titanium oxide (TiO_2), cerium oxide (CeO_2), or zirconium oxide (ZrO_2).

[0036] In addition, the refractive index of the low refractive index layer L that makes up the thin optical film (3) is as low as possible, and more concretely, it is preferable if it is over 1.3 or under 1.5. This is based on the same idea as the high refractive index material described above, even with low refractive index material, and in cases where the refractive index of the low refractive index layer L is larger than even 1.5, it is because the necessity arise of many numbers of layers in order to realize the fixed selected reflection spectrum, and, because thin optical film material for which the refractive index is less than 1.3 does not exist in great numbers, and the allowance selected for material combinations for the low refractive index layer L is narrow. It is possible to construct a low refractive index layer L that has this kind of refractive index from low refractive index material such as magnesium fluoride (MgF_2).

[0037] In addition, this projector screen (1) possesses a light diffusion layer (4) on the thin optical film (3) as shown in Fig. 1. With the projector screen (1), because it reflects light for the narrow-band primary color wavelength region through possession of a thin optical film (3), the reflected image of the image projected on to this projector screen (1) comes to be seen, and, specifically, only the reflected light of the image projected onto the projector screen comes to be seen. However, cases where the light reflected by the screen is only the reflected specula elements poses a disadvantage for viewers due to the limited field of vision, etc.

[0038] At this point, by having a light diffusion layer (4) on the projector screen (1), the screen is constructed in a way that makes it possible to view the diffuse reflectance light from the projector screen. The light diffusion layer (4) is composed so that fixed wavelength region light, namely narrow-band primary color wavelength light is selectively diffused. In particular, the light diffusion layer (4) has light scattering properties with regards to narrow-band primary color wavelength region light. As shown in Fig. 1, by assuming a construction in which a light diffusion layer (4) is in place on the thin optical film (3), light that passes through the light diffusion layer (4), and then is reflected by the thin optical film (3) again passes through the light diffusion layer (4). This time, because the light reflected by the thin optical film (3) is diffused when it passes through the light diffusion layer (4), it is possible to obtain diffuse reflectance light other than the reflected specula elements. Then, since reflected specula elements and diffuse reflectance light come to exist, with regards to reflected light from the projector screen (1), viewers come to be able to see diffuse reflectance light other than the reflected specula elements, and the viewing field properties greatly improve. As a result, it becomes possible for the viewer to see natural images.

[0039] In addition, the diffuse reflectance light is one in which light reflected by the thin optical film (3) is diffused. Then, fixed wavelength region light, specifically narrow-band primary color wavelength light, is reflected by the thin optical film (3), so the diffuse reflectance light also comes to be almost entirely narrow-band primary color wavelength light. Accordingly, even in cases where outside light incidences the projector screen (1), since the light that is outside of the narrow-band primary color wavelength light does not become diffuse reflectance light, there is no drop in contrast or occurrence of outside light reflected as a result of the effect of the light diffusion layer (4), but it becomes possible to obtain favorable viewing field properties.

[0040] For example, in cases where a screen construction is considered in which a thin optical film for constructing a multilayer thin film of reflectance R is established underneath, with a light diffusion layer of scattering coefficient S as the outermost layer, when the intensity of the incident light on the screen is assumed to be 1, the diffusion light intensity Is from this screen is expressed by the formula (5) below.

[0041]

$Is = 1 \cdot S + (1-S)\,RS \ldots (5)$

[0042] On one hand, reflected specula element Ir is as in formula (6) below.

[0043]

$Ir = (1-S)\,R\,(1-S) \ldots (6)$

[0044] Logically, in order to understand easily, in cases where R=1, or R=0 are considered, the situation is as follows.

[0045] First, in cases where R=1, formulas are as in (7)~(9) below.

$$Is = 1 \cdot S + (1-S)\,S = S\,(2-S) \ldots (7)$$
$$Is = (1-S)^2 \ldots (8)$$
$$Is/Ir = S\,(2-S) / (1-S)^2 \ldots (9)$$

[0046] In addition, in cases where R=0, formulas are as in (10), and (11) below.

$Is = 1 \cdot S \ldots (10)$

$Ir = 0 \ldots (11)$

[0047] When this is shown by a diagram, it appears as in Fig. 2. According to Fig. 2, in cases where the value of the scattering coefficient S increases from 0 to 1, the value of the diffuse light intensity Is (R=1) for reflectance R=1 becomes 2x the value of

the diffuse light intensity Is (R=0) for reflectance R=0 when the value of S is small, but by the value of S approaching 1, then it is understood that there is no difference between the diffuse light intensity Is (R=1) for reflectance R=1 and the diffuse light intensity Is (R=0) for reflectance R=0.

[0048] For example, if there are spectrum properties in the scattering coefficient S, the scattering coefficient is also large for the wavelength range of reflectance R=1, and it is possible to realize a light diffusion layer for which the scattering coefficient becomes smaller for the wavelength range of reflectance R=0, then, in cases where the spectral scattering properties are smooth, it is possible for the ratio of the diffuse light intensity, which is about 2 as stated above, to become larger.

[0049] Light diffusion layers that have these kinds of spectral scattering properties can be constructed, for example, through use of metal micro particles. For example, it is possible to have a light diffusion layer constructed by suspending metal micro particles within a specific medium. Light diffusion layers that are constructed by suspending metal micro particles in this manner have excellent light scattering properties with regards to light of a specific wavelength range, depending on the type of metal micro particles used, their size, and the terms of the refractive index, etc. of the medium in which the metal micro particles are suspended. Specifically, it is possible to realize projector screens with excellent light scattering properties with regards to a specific wavelength range if it possesses this kind of light diffusion layer.

[0050] It is possible to use silver particles to illustrate the kinds of metal micro particles that can be used to construct this kind of light diffusion layer. For example, a light diffusion layer that is composed of spherical silver particles of radius 25nm suspended in a 1.49 grade medium has excellent light scattering properties with regards to light for blue wavelength regions. Specifically, it is possible to realize a projector screen that has excellent light scattering properties with regards to light for blue wavelength regions through possession of a light diffusion layer that is constructed using silver particles.

[0051] In cases where the projector screen (1) is constructed with a light diffusion layer (4), constructed using silver particles in this manner, in place on the thin optical film (3), for example, the narrow-band primary color wavelength light within the light that passes through the particular light diffusion layer (4) is reflected by the thin optical film (3), and then returned again to the light diffusion layer (4). Then, the light for the blue wavelength regions within the narrow-band primary color wavelength light returned to the light diffusion layer (4) is further diffused and forms diffuse reflectance light when passing through the light diffusion layer (4). Specifically, with regards to blue wavelength region light, since reflected specula elements and diffuse reflectance light come to exist, the viewing field properties are greatly improved, and it becomes possible to realize projector screens with excellent visibility.

[0052] In addition, although, as described above, there is no significant improvement, in viewing field properties, a supplementary heightening of the viewing field properties for a specific wavelength is possible through use of this kind of light diffusion layer. For example, in cases where a single spherical silver particle of radius of about 40nm is suspended in a 1.6 grade medium, it has excellent light scattering properties for green wavelength region light. However, in cases where many of these spherical silver particles are suspended in the same medium, it has light scattering properties with a gradual peak for green wavelength region light.

[0053] At this point, by having a light diffusion layer, constructed by suspending many spherical silver particles in the same kind of medium in this manner, installed in place, the viewing field properties for the green wavelength region are not greatly improved, but it is possible to get supplementary improvement. This kind of scattering layer is good in cases where plans are made for micro-adjusting the balance setup with other wavelength regions.

[0054] Furthermore, since, with light diffusion layers constructed by suspending metal micro particles in a medium in this manner, the weight of the metal micro particles per unit area effects the scattering properties of the light diffusion layer, based on the distribution density of the metal micro particles and the thickness of the scattering layer, it is good to consider these points when establishing the distribution quantity of metal micro particles.

[0055] In addition, it is possible to use copper particles as metal micro particles that can be used to construct this kind of light diffusion layer. Since copper particles have excellent light scattering properties with regards to red wavelength region light, it is possible to construct a light diffusion layer that has excellent light scattering properties with regards to red wavelength region light through use of copper particles. Specifically, it is possible to realize projector screens that have excellent light scattering properties with regards to red wavelength region light by possessing a light diffusion layer constructed using copper particles.

[0056] In cases where a projector screen is constructed with a light diffusion layer, constructed using copper particles in this manner, installed on the thin optical film (3), the narrow-band primary color wavelength light within the light that passes through the particular light diffusion layer (4) is reflected by the thin optical film (3) and then again is returned to the light diffusion layer (4). Then, the red wavelength region light within the narrow-band primary color wavelength region light returned to the light diffusion layer (4) is further diffused and forms diffuse reflectance light when it passes through the light diffusion layer (4). Specifically, because reflected specula elements and diffuse reflectance light come to exist with regards to the red wavelength region light, the viewing field properties are heightened, and it becomes possible to realize projector screens with excellent visibility.

[0057] In addition, it is possible to use gold particles as the metal micro particles described above. Light diffusion layers construction using gold particles have light scattering properties with regards to green wavelength region light. Specifically, it is possible to realize projector screens that have light scattering properties with regards to green wavelength region light through possession of a light diffusion layer constructed using gold particles.

[0058] In cases where a projector screen is constructed with a light diffusion layer, constructed using gold particles in this manner, installed on the thin optical film (3), the narrow-band primary color wavelength light within the light that passes through the particular light diffusion layer (4) is reflected by the thin optical film (3) and then again is returned to the light diffusion layer (4). Then, the green wavelength region light within the narrow-band primary color wavelength region light returned to the light diffusion layer (4) is further diffused and forms diffuse reflectance light when it passes through the light

diffusion layer (4). Specifically, because reflected specula elements and diffuse reflectance light come to exist with regards to the green wavelength region light, the viewing field properties are heightened, and it becomes possible to realize projector screens with excellent visibility.

[0059] In addition, it is possible to use nickel particles as the metal micro particles described above. In cases where a single nickel particle is suspended in a medium with a refractive index of 1.6 degrees, it has light scattering properties mainly with regards to green wavelength region light. However, in cases where several of these spherical nickel particles are suspended in the same medium, it has broad light scattering properties.

[0060] At this point, by placing a light diffusion layer constructed by suspending many of this kind of spherical nickel particle in the same medium, although the viewing field properties of the specific wavelength regions within light for regions of blue wavelength, green wavelength, and red wavelength region are not greatly improved, it is possible to obtain an overall improvement in viewing field properties for all wavelength regions for blue wavelength, green wavelength and red wavelength regions. As a result, it is possible to plan for micro adjustments of the overall image contrast and brightness. Specifically, it is possible to realize projector screens with good overall image contrast and brightness through possession of a light diffusion layer constructed using nickel particles.

[0061] It is acceptable whether the light diffusion layer (4) described above has only one layer in place or has multiple light diffusion layers (4) in place, based on the projector screen's intended use, etc. Furthermore, it is acceptable whether the light diffusion layer (4) is in place on the thin optical film (3), or more specifically, on the outermost layer of the dielectric multilayer film, or is an interlayer of the dielectric multilayer film. Whatever the case, it is possible to obtain the same effects as mentioned above.

[0062] In addition, it is not necessary for this kind of light diffusion layer (4) to be constructed as a layer separate from the thin optical film (3), which is distributed within a medium, as described above, but, for example, it is acceptable if a construction is assumed in which the low refractive index layer functions as a light diffusion layer, due to the suspension of a fixed number of metal micro particles in a low refractive index layer, for example. By assuming this kind of construction, since it is possible to simplify the construction of the projector screen, it is then possible to plan for the minimization of the projector screen thickness.

[0063] The protective layer (5) does not function optically, specifically, it does not function as a band filter, but is a layer for protecting the scattering layer (4) and thin optical film (3) from the exterior. For example, in case where the high refractive index layer is constructed using zinc sulfide (ZnS), zinc sulfide is weak against moisture, so in cases where the projector screen is used in environments with high humidity and gets water on it, there is a risk of the thin optical film (3) deteriorating, and an even further risk of the screen experiencing a drop in durability and quality. In addition, there is a risk of durability or quality decreasing in cases where abrasions or scratches are produced by some external cause. At this point, by forming the protective layer (5), the scattering layer (4) and thin optical film (3) are protected, and it is possible to realize a projector screen with excellent durability and quality.

[0064] In addition, with regards to diffraction grating-type projector screens, it is possible to use diffraction grating-type projectors (11) that are constructed using the following GLV.

[0065] As shown in Fig. 3, diffraction grating-type projector devices (11) are equipped with a No. 1 laser oscillator 21r, a No. 2 laser oscillator 21g, and a No. 3 laser oscillator 21b, light sources that individually emit red, green, and blue light. Furthermore, the following explanation generically refers to No. 1 or No. 3 laser oscillators 21r, 21g, and 21b, and in some cases refers simply to laser oscillator 21. These laser oscillators (21) can be constructed using semiconductor laser elements or solid laser elements that emit light of each color. Then, the laser light emitted from No. 1 or No. 3 laser oscillator 21r, 21g, and 21b is individually turned into narrow-band primary color wavelength region light: wavelength 642nm red laser light, wavelength 532nm green laser light and wavelength 457nm blue laser light.

[0066] In addition, with diffraction grating-type projector devices (11), a red collimator lens 22r, green collimator lens 22g, and blue collimator lens 22b are individually installed on the optical paths for the light emitted by each of the laser oscillators (21). Furthermore, these collimator lenses are generically referred to as a group as simply collimator lenses (22). Thus, through these collimator lenses (22), the light emitted by each laser oscillator (21) is turned into parallel light, and then incidences on the cylindrical lens (23). Light that incidences on the cylindrical lens (23) is focused onto the GLV (24) by this cylindrical lens.

[0067] Specifically, with diffraction grating-type projector devices (11), although they do not use light from a single light source, they possess light sources that independently emit three individual colors of light via each laser oscillator (21). In addition, with diffraction grating-type projector devices (11), the construction is such that the light emitted by each laser oscillator (21) directly incidences on the cylindrical lens (23) via the collimator lens (22).

[0068] Here is an explanation of GLV24. First, we will explain the principle of GLV. GLV are formed by many minute ribbons on a substrate through various types of semiconductor manufacturing technology. Then, each of these ribbons is able to freely rise or drop according to piezoelectric elements, etc. GLV constructed in this manner dynamically drive the height of each of the ribbons, and by radiating light for fixed wavelength regions, overall they form phase-type diffraction grating (grating). Specifically, GLV produces ±primary (or higher order) diffracted light by radiating light.

[0069] Here, light is radiating against a GLV of this type, and due to shading of 0-order diffracted light, the diffracted light is flashed due to each of the GLV ribbons being driven up and down, and as a result, it is possible to display images.

[0070] For example, various proposals are being made for display devices that display images using the properties of GLV described above. With these kinds of display devices, when the elements of the flat images to be displayed (referred to as pixels below) are displayed, they are shown as one pixel for approximately six ribbons. In addition, the groupings of ribbons corresponding to one pixel interchangeably raise and drop each of the adjacent neighboring ribbons.

[0071] However, if it is possible to independently arrange each ribbon in the GLV, and to operate each one independently of another, then it is possible to generate optional one-dimensional phase distributions. It is possible to think of GLV constructed in

this manner as a reflecting-type one-dimensional phase type space modulator.

[0072] In cases where GLV is constructed as a reflecting-type one-dimensional type space modulator, an optional phase distribution is generated by independently driving each of the individual ribbons (31) of the GLV (31), as shown in Fig. 4, for example. It is possible, with this GLV (31), to modulate and reflect this incidence light, by incidence of the fixed wavelength region light that forms the phase as shown by the arrows in Fig. 4, and, as shown in Fig. 5, to generate an optional one-dimensional wave front.

[0073] GLV (24) constructed by using this principle has many minute ribbons (42) formed on the substrate (41), as shown in Fig. 6. Each ribbon (42) possesses a drive component (43) constructed from such elements as an electric drive circuit and wiring, and through this drive component (43), freely drives it up and down against the principal plain of the substrate (41).

[0074] In addition, each ribbon (42) is arranged in a single dimension in GLV (24), creating rows of ribbons. Multiple rows of ribbons are set per wavelength region for the incoming light. More specifically, for example, as shown in Fig. 6, GLV (24) are constructed so that three colors of light – red light, green light, and blue light – incidence, and at the locations where these lights incidence, the individual ribbon rows for red ribbon row 44r, green ribbon row 44g, and blue ribbon row 44b are arranged in mutually parallel positions. Furthermore, below these ribbon rows are generically referred to as 44r, 44g, and 44b, and more simply referred to as ribbon row 44. Here, red ribbon row 44, green ribbon row 44g, and blue ribbon row 44b are explained ideally in terms of being arranged within the same plane, but if the relationship of the plane positions is maintained, then, although it is not important to always make arrangements on the same plane, normally, arrangements are made on separate planes.

[0075] Thus, it is made possible for each ribbon row (44) to have each ribbon (42) driven independently, and, as explained for each case in Fig. 4 and Fig. 5, it is made possible to generate an optional phase distribution. Accordingly, GLV (24) are able to generate an optional one-dimensional wave front independently per each color, for incoming red light, green light, and blue light, via the individual red ribbon row 44r, green ribbon row 44g, and blue ribbon row 44b.

[0076] Accordingly, GLV (24) spatially modulate each of the individual three colors of light that incidence through the red ribbon row 44r, green ribbon row 44g, and blue ribbon row 44b, and reflects them as an optional one-dimensional wave front. Specifically, GLV (24) accomplish the function of a spatial modulator for the display device (30).

[0077] GLV (24) constructed as in the above can be constructed using various types of semiconductor manufacturing technology, and can be operated quite quickly. Accordingly, it is possible to assume that it is appropriate to use them as a spatial modulators for an image display device, for example. In addition, GLV (24) possess a ribbon row (44) per wavelength region light to be converted, and since these ribbon rows (44) are in place as a single body on the substrate (41), in cases where they are used as a spatial modulator for the image display device, it is possible not only to reduce the parts count, but it is possible to assume that positioning of the ribbon rows per light for each wavelength region is unnecessary.

[0078] In addition, with diffraction grating-type projector devices (11), the light modulated and reflected by GLV (24) is made into parallel light by the cylindrical lens (23), together with being made again to incidence against this cylindrical lens (23). Then, a No. 1 thick hologram element 25a and No. 2 thick hologram element 25b are in place on the optical path of the light that is made into parallel light by the cylindrical lens (23).

[0079] With these No. 1 and No. 2 thick hologram elements 25a and 25b, one example is when blue light WB is diffracted along the same direction as red light WR by No. 2 thick hologram element 25b, along with red light WR being diffracted by No. 1 thick hologram element 25a. In addition, these No. 1 and No. 2 thick hologram elements 25a and 25b allow green light WG to pass directly without diffraction, and make it so that it is emitted along the same direction as red light WR. In this manner, the three colors of light modulated by GLV (24) are brought together and emitted along a uniform direction. Specifically, it can be said that there is a mechanism for uniting waves together through these No. 1 and No. 2 thick hologram elements 25a and 25b, for this diffraction grating-type projector device (11).

[0080] Then, light for which the waves have been united through the No. 1 and No. 2 thick hologram elements 25a and 25b are scanned along a fixed direction by a galvano-meter mirror, and then are projected onto a projector screen (1) via a projection lens (27). As a result, diffraction grating-type projector devices (11) are constructed to display images that are color projected onto projector screens (1).

[0081] As explained above, with projector screens (1) which utilize this invention, narrow-band primary color wavelength region light emitted from a diffraction grating-type projector device (11) passes through the protective film (5) and light diffusion layer (4), incidences on the thin optical film (3), and then is reflected by the applicable thin optical film (3). Then, this reflected light again incidences the light diffusion layer (4), is diffused by a fixed ratio, passes through the protective film (5) as diffuse reflectance light, and then is emitted. In addition, reflected light that was not diffused by the scattering layer (4) passes through the protective film (5) as reflected specula elements, and then is emitted. As a result, since reflected specula elements and diffuse reflectance light come to exist as light reflected from the projector screen (1), even in cases where the viewer's eyes divert from the running and parallel directions of the reflected specula elements, it becomes possible to view diffuse reflectance light, which is made to have excellent visibility.

[0082] In addition, reflected specula elements and diffuse reflectance light is light that is reflected by the thin optical film (3), and since fixed wavelength region light, namely narrow-band primary color wavelength region light, is selectively reflected by the thin optical film (3), both the reflected specula elements and diffuse reflectance light almost completely become narrow-band primary color wavelength light. Accordingly, even in cases where outside light incidences the projector screen (1), since hardly any light outside of narrow-band primary color wavelength light becomes reflected light, it is possible to obtain bright images, along with being possible to effectively reduce drops in image contrast and outside light reflection caused by outside light. As a result, with this projector screen (1), it is possible to obtain clear images even in cases of bright projection environments, and to provide clear images without any effect from the brightness of the projection environment.

[0083] In addition, it is possible to assume light for wavelength regions that have a wavelength spread of a certain extent, without limiting the light source used for projection to narrow-

band primary color wavelength region light, and in such cases, it is desirable for the optical thickness *nd* of each layer of the applicable dielectric multilayer film to satisfy the condition of the formula (12) below, with regards to the main wavelength λp for the applicable wavelength region light.

$$nd=\lambda\ (\alpha\pm 1/4) \quad (\alpha \text{ is a natural number}) \ldots (12)$$

This is an item that shows that it is possible to assume the same composition by replacing the construction of the multilayer film for the narrow-band primary color wavelength region light with the main wavelength λp with the applicable wavelength region light, and that, in the same way, it is possible to obtain sufficient selectivity for penetrating light and reflected light.

[0084]

[Implementation Example] Below, we will further explain this invention in detail based on concrete examples of implementation. Furthermore, this invention is not limited to the following implementation examples, and appropriate changes are possible within a range that does not deviate from the principles of this invention.

[0085] [Example 1] In Example 1, the projection screen related to this invention is a diffraction grating-type projector screen that was constructed that possessed a thin optical film that functioned as a narrow-band primary color wavelength region filter. This diffraction grating-type projection screen was capable of being used, for example, in projecting with a diffraction grating-type projector, as shown in Fig. 3 described above.

[0086] A diffraction grating-type projector screen (51) manufactured by preparing a screen substrate (52) that consisted of black PET of thickness 500μm as a screen substrate, and by forming a thin optical film (53) that consisted of a dielectric multilayer film on the surface of one side of the applicable screen substrate (52).

[0087] The thin optical film (53) is formed as a dielectric multilayer film, formed by spattering with seven alternating layers of high refractive index layers H11~H14 that are dielectric thin film consisting of high refractive index material, and low refractive index layers L11~113 that are dielectric thin film consisting of low refractive index material. In this implementation example, the refractive index of the high refractive index layers is set for a comparative rise from the viewpoint of reducing the residual transmittance of the three color wavelengths of blue wavelength, green wavelength, and red wavelength, and a refractive index of 2.4 is assumed for the high refractive index layer according to concrete formation from zinc sulfide (ZnS). In addition, the low refractive index layer is formed from magnesium fluoride (MgF2), and a refractive index of 1.4 is assumed for the low refractive index layer.

[0088] Then, when it is assumed that the refractive index of each layer of the dielectric multilayer film is *n*, and the film thickness of each layer is *d*, the dielectric multilayer film is constructed so that the optical thickness *nd* for each dielectric multilayer film satisfies the conditions of the formula (13) below, with regards to the wavelength λ for each emission from the narrow-band primary color light source, and a thin optical film (52) is assumed. In addition, in this implementation example, the optical thickness *nd* for each dielectric thin film is set so that it reaches close to 1.467μm.

[0089]

$$nd=\lambda\ (\alpha\pm 1/4) \quad (\alpha \text{ is a natural number}) \ldots (13)$$

[0090] The following shows the conditions for forming the thin optical film (53) manufactured in Example 1.

[0091] <u>Thin optical film formation conditions</u>

Refractive index for high refractive index layers: $n_H=2.4$
Refractive index for low refractive index layers: $n_L=1.4$
Film thickness of high refractive index layers: $d_H=611nm$
Film thickness of low refractive index layers: $d_L=1047nm$
Layer count for high refractive index layers: 4 layers
Layer count for low refractive index layers: 3 layers
Refractive index for empty space (air): $n_o=1$
Refractive index of screen substrate: $n_g=1.49$
Optical thickness: $n_d=1.467\mu m$

[0092] Spectral transmittance characteristics were measured for S-polarization and P-polarization within a range of wavelength region 400~700nm for projector screens manufactured according to the above. It was assumed that the angle of incidence with the screen was 15°. The results are shown in Fig. 8.

[0093] As understood from Fig. 8, the transmittance of the light for blue wavelengths (close to 450nm), green wavelengths (close to 540nm), and red wavelengths (close to 650nm) is becoming very low, and the light for wavelengths outside of this is showing high permeation characteristics. This shows that blue wavelength, green wavelength, and red wavelength light is being effectively reflected by the thin optical film (52), and the projector screen (51) in this implementation example selectively reflects the light for blue wavelength, green wavelength and red wavelength, and it is understood that light for wavelengths outside of this is selectively allowed to penetrate. Then, since screen substrate (52) that consists of black PET is being used, and the particular screen substrate (52) functions as a light absorption layer, the light that penetrates the thin optical film (53) is absorbed by the screen substrate (52), and there is no reflection.

[0094] Specifically, with the projector screen (50), only blue wavelength, green wavelength, and red wavelength light is obtained as reflected light, and since it is possible to largely control the reflection of outside light in comparison to conventional screens, it is possible to obtain a bright image, together with it being possible to effectively reduce the drop in the contrast of images formed on the projector screen (51) and the reflection of outside light. Accordingly, as determined by this implementation example, it can be said that it is possible to realize projector screens for which it is possible to obtain a clear image with high contrast and without being affected by the brightness of the projection environment.

[0095] In addition, normally, when a thin film is formed on the screen, the viewing field angle becomes narrow, but according to the aforementioned results, acceptable results are being obtained even if the angle of incidence is 0°, or more

specifically, is not vertical to the screen, and it is understood that it is possible to realize projector screens for which the degree of freedom of the incidence light against the projector screen is large. and that have excellent practical utility.

[0096] In addition, the optical thickness *nd* for each dielectric thin film was changed and the average transmittance (%) measured, and the optimum range for the optical thickness *nd* investigated, by changing the film thickness of each dielectric thin film that makes up the thin optical film (53) under the aforementioned conditions.

[0097] According to the results of Fig. 9, good average transmittance is being obtained for the optical thickness *nd* of each dielectric thin film within a range of 1.462μm~1.467μm, and as a result, the optimum range of the optical thickness *nd* for each dielectric thin film is understood to be 1.462μm~1.467μm.

[0098] [Example 2] In Example 2, it was assumed that the refractive index of the high refractive index layer was 2.7, due to the formation of the high refractive index layer from titanium oxide (TiO_2), and other than assuming that the film thickness of the high refractive index layer was 543nm, the projector screen was made the same as in Example 1. Below shows the formation conditions of the thin optical film manufactured in Example 2.

[0099] <u>Thin optical film formation conditions</u>
Refractive index for high refractive index layers: n_H=2.7
Refractive index for low refractive index layers: n_L=1.4
Film thickness of high refractive index layers: d_H=543nm
Film thickness of low refractive index layers: d_L=1047nm
Layer count for high refractive index layers: 4 layers
Layer count for low refractive index layers: 3 layers
Refractive index for empty space (air): n_o=1
Refractive index of screen substrate: n_g=1.49
Optical thickness: n_d=1.467μm

[0100] Spectral transmittance characteristics were measured for S-polarization and P-polarization within a range of wavelength region 400~700nm, the same as in Example 1, for projector screens manufactured according to the above. It was assumed that the angle of incidence of the light with the screen was 15°. The results are shown in Fig. 10.

[0101] As understood from Fig. 10, the transmittance of the light for blue wavelength, green wavelength and red wavelength is getting even lower than in the case of Example 1, specifically, it is understood that the residual transmittance of light for blue wavelength, green wavelength, and red wavelength is further dropping. This shows that blue wavelength, green wavelength, and red wavelength light is further being effectively reflected. On one hand, it is understood that the transmittance of high transmittance bands centered on the yellow wavelength is dropping slightly in comparison to Example 1. This shows that the transmittance of high transmittance bands centered on the yellow wavelength is dropping slightly in comparison to Example 1.

[0102] According to this, it is possible to change the properties of the thin optical film by adjusting the refractive index of the high refractive index layer for a seven layer construction that is the same as in Example 1, for example, it is possible to establish better conditions for the blue wavelength, green wavelength, and red wavelength light reflectance by setting the refractive index of the high refractive index layer to a high value of about 2.7, and it can be said that it is possible to obtain a brighter image.

[0103] Accordingly, by considering the effects of Example 1 as well, the light of blue wavelength, green wavelength, and red wavelength is selectively reflected by assuming that the refractive index of the high refractive index layer is over 2.4, light for other wavelengths is selectively allowed to penetrate, contrast is high, and it can be said that it is possible to realize projection screens for which it is possible to obtain clear images without any effect from the brightness of the projection environment. Then, it is possible to set the refractive index of the high refractive index layer at a high value, 2.7 for example, in congruence with the intended use of the screen.

[0104] In addition, in this implementation example as well, it is assumed that the angle of incidence of the light is 15°, the same as in Example 1, and it is understood that it is possible to realize projection screens with a large degree of freedom for the incidence light against the projection screen with the construction in this implementation example, and are excellent in their practical utility.

[0105] [Example 3] From the viewpoint of lowering the residual transmittance of the light for blue wavelength, green wavelength and red wavelength in Examples 1 and 2, specifically, from the viewpoint of raising the reflectance of the light for blue wavelength, green wavelength, and red wavelength, the refractive index of the high refractive index layer was set high, but, on the other hand, the average transmittance in other wavelength regions drops slightly. At that point, when thought is given to the refractive index for which the ratio of the residual transmittance and the average transmittance of the visible light band is maximized, the refractive index for the high refractive index layer exists at around 2.1~2.2, as shown in Fig. 11, with regards to the integral of the refractive index for which the ratio of the residual transmittance and the average transmittance of the visible light band is maximized for a seven layer construction the same as in Examples 1 and 2. In Fig. 11, the vertical axis shows the ratio of the residual transmittance and the average transmittance for the visible light band.

[0106] At this point, with Example 3, it is assumed that the refractive index of the high refractive index layer is 2.1, due to the formation of the high refractive index layer from cerium oxide (CeO_2), and that other than assuming that the film thickness of the high refractive index layer is 698nm, the projection screen is manufactured the same as in Example 1. Below shows the conditions for formation of the thin optical film manufactured in Example 3.

[0107] <u>Thin optical film formation conditions</u>
Refractive index for high refractive index layers: n_H=2.1
Refractive index for low refractive index layers: n_L=1.4
Film thickness of high refractive index layers: d_H=698nm
Film thickness of low refractive index layers: d_L=1047nm
Layer count for high refractive index layers: 4 layers
Layer count for low refractive index layers: 3 layers
Refractive index for empty space (air): n_o=1
Refractive index of screen substrate: n_g=1.49
Optical thickness: n_d=1.467μm

[0108] Spectral transmittance characteristics were measured for S-polarization and P-polarization within a range of wavelength region 400~700nm, the same as in Example 1, for projector screens manufactured according to the above. It was assumed that the angle of incidence of the light with the screen was 15°. The results are shown in Fig. 12

[0109] From Fig. 12, it is understood that sufficient low values are being shown for cases where the transmittance of light for blue wavelength, green wavelength and red wavelength is becoming slightly higher than in Example 1. Specifically, it is

understood that favorable reflection properties are being shown with regards to light for blue wavelength, green wavelength, and red wavelength. In addition, favorable transmittance characteristics are being shown for other wavelength regions, even in comparison to Examples 1 and 2. According to these, it is understood that projector screens in this implementation example selectively reflect light for blue wavelengths, green wavelengths and red wavelengths, and that light for other wavelengths is effectively allowed to penetrate.

[0010] In addition, as shown in Fig. 12, with this implementation example, exclusion bands, specifically the amplitudes for reflection bands with regards to blue wavelength, green wavelength, and red wavelength light, are becoming relatively narrow. This is favorable since it shows that only light for narrower wavelength regions is reflected, and that it is possible to better improve the contrast.

[0111] Accordingly, per this implementation example, it is possible to realize projector screens for which it is possible to obtain clear images with high contrast and without any effect from the brightness of the projection environment.

[0112] In addition, in this implementation example as well, it is assumed that the angle of incidence of the light is 15°, the same as in Example 1, and it is understood that it is possible to realize projection screens with a large degree of freedom for the incidence light against the projection screen with the construction in this implementation example, and that are excellent in their practical utility.

[0113] As explained above, it is possible to realize projector screens that have high reflectance for primary color wavelength regions and high transmittance with wavelength regions other than these, through use of the thin optical film shown in Examples 1 and 3.

[0114] [Example 4] In Example 4, an investigation was conducted into light diffusion layers that have spectral scattering properties by using spherical silver particles as metal micro particles and projector screens that possess these. First, the values for the real part *n* of the complex refractive index of silver, specifically the refractive index, and the imaginary part *k*, specifically the extinction coefficient, are as shown in Fig. 13. The vertical axis in Fig. 13 shows the real part *n* and imaginary part *k*, while the horizontal axis shows the wavelength.

[0115] At this point, the scattering efficiency, excluding the scattering cross section by the projection area, when spherical silver particles of radius 25nm are suspended in a medium of refractive index 1.49, becomes as in Fig. 14. The scattering efficiency was obtained through calculation of the Mie scattering using the complex refractive index.

[0116] In Fig. 14, the vertical axis shows the scattering efficiency, specifically the possibility of multiple scattering of the projection area. According to Fig. 14, the scattering efficiency maximizes for wavelength 457nm, and it is understood that it is possible to scatter light by about 7x for the projection area.

[0117] Next, a scattering film was formed by suspending these spherical silver particles in the same medium for which the number density becomes qty. $3x10^{10}/cm^3$. The film thickness of the scattering film was assumed to be about 775μm. Then, we searched for the scattering coefficient when a scattering film formed in this manner underwent multiple scattering. The results are shown in Fig. 15. The vertical axis in Fig. 15 shows the scattering coefficient. The peak scattering coefficient according to Fig. 15 is close to wavelength 450nm, and specifically becomes 0.4 in the blue wavelength regions. This shows that 40% light will scatter. Due to this, it can be said that it is possible to realize a light diffusion layer that possesses wavelength selectivity for which it is possible to selectively scatter light for the blue wavelength regions by suspending spherical silver particles of radius 25nm in a medium of refractive index 1.49. At this point, the factor that affects the peak scattering coefficient is the weight of the silver particles per unit area according to the number density of the spherical silver particles and the film thickness of the scattering film, and in this case, is $1.5mg/ft^2$, or more specifically $0.135mg/m^2$.

[0118] Next, it is understood that the scattering rate of blue wavelength region light is improving in comparison to other wavelength regions, as shown in Fig. 16, when an investigation is made into when this scattering layer is placed on the thin optical film (53) of the projector screen (51) in Example 1. According to this, it can be said that it is possible to realize projector screens with good scattering properties and excellent visibility for the blue wavelength regions, by placing the light diffusion layer described above on the projector screen (51) in Example 1. Furthermore, the vertical axis in Fig. 16 shows the total of the scattering rate and the reflectance with the scattering rate.

[0119] [Example 5] In Example 5, an investigation was conducted into light diffusion layers that have spectral scattering properties by using spherical copper particles as metal micro particles and projector screens that possess these. First, the values for the real part *n* of the complex refractive index of copper, specifically the refractive index, and the imaginary part *k*, specifically the extinction coefficient, are as shown in Fig. 17. The vertical axis in Fig. 17 shows the real part *n* and imaginary part *k*, while the horizontal axis shows the wavelength.

[0120] At this point, the scattering efficiency, excluding the scattering cross section by the projection area, when spherical silver particles of radius 49nm are suspended in a medium of refractive index 1.6, becomes as in Fig. 18. The scattering efficiency was obtained through calculation of the Mie scattering using the complex refractive index. In Fig. 18, the vertical axis shows the scattering efficiency, specifically the possibility of multiple scattering of the projection area. According to Fig. 18, the scattering efficiency maximizes for wavelength 632nm, and it is understood that it is possible to diffuse light by about 6x for the projection area.

[0121] Next, a scattering film was formed by suspending these spherical copper particles in the same medium for which the number density becomes qty. $0.8x10^{10}/cm^3$. The film thickness of the scattering film was assumed to be about 550μm. Then, we searched for the scattering coefficient when a scattering film formed in this manner underwent multiple scattering. The results are shown in Fig. 19. The vertical axis in Fig. 19 shows the scattering coefficient. The peak scattering coefficient according to Fig. 19 is close to wavelength 640nm, and specifically becomes 0.3 in the red wavelength region. This shows that 30% light will scatter. Due to this, it can be said that it is possible to realize a light diffusion layer that possesses wavelength selectivity for which it is possible to selectively scatter light for the red wavelength regions by suspending spherical copper particles of radius 49nm in a medium of refractive index 1.6.

[0122] Next, it is understood that the scattering rate of red wavelength region light is improving in comparison to other wavelength regions, as shown in Fig. 20, when an investigation

is made into when this scattering layer is placed on the thin optical film (53) of the projector screen (51) in Example 1. According to this, it can be said that it is possible to realize projector screens with good scattering properties and excellent visibility for the red wavelength regions, by placing the light diffusion layer described above on the thin optical film (53) of the projector screen (51) in Example 1. Furthermore, the vertical axis in Fig. 20 shows the total of the scattering rate and the reflectance with the scattering rate.

[0123] In addition, the characteristics in cases where light diffusion layers using the spherical silver particles in Example 4 and light diffusion layers using the spherical copper particles in Example 5 are overlapped and used with the projector screen in Example 1 are as shown in Fig. 21. According to Fig. 21, it is understood that the scattering rate is improving and favorable visibility is obtained for blue wavelength regions close to wavelength 457nm and red wavelength regions close to wavelength 642nm.

[0124] One on hand, it is understood that the scattering rate is getting lower in comparison to blue wavelength regions and red wavelength regions, and that visibility deteriorates slightly for green wavelength regions close to wavelength 532nm. In cases such as this, it is possible to supplement the scattering rate for green wavelength regions by using supplementary means as explained in Example 6 and 7, and construct projector screens (51) with a good visibility balance.

[0125] [Example 6] In Example 6, an investigation was conducted into light diffusion layers that have spectral scattering properties by using spherical gold particles as metal micro particles and projector screens that possess these. First, the values for the real part *n* of the complex refractive index of gold, specifically the refractive index, and the imaginary part *k*, specifically the extinction coefficient, are as shown in Fig. 22. The vertical axis in Fig. 22 shows the real part *n* and imaginary part *k*, while the horizontal axis shows the wavelength.

[0126] At this point, the scattering efficiency, excluding the scattering cross section by the projection area, when spherical gold particles of radius 20nm are suspended in a medium of refractive index 1.49, becomes as in Fig. 23. The scattering efficiency was obtained through calculation of the Mie scattering using the complex refractive index. In Fig. 23, the vertical axis shows the scattering efficiency, specifically the possibility of multiple scattering of the projection area. According to Fig. 23, it is understood that the scattering efficiency maximizes for wavelength 550nm.

[0127] Next, a scattering film was formed by suspending these spherical copper particles in the same medium for which the number density becomes qty. $5x10^{11}/cm^3$. The film thickness of the scattering film was assumed to be about 444μm. Then, we searched for the scattering coefficient when a scattering film formed in this manner underwent multiple scattering. The results are shown in Fig. 24. The vertical axis in Fig. 24 shows the scattering coefficient. The peak scattering coefficient according to Fig. 24 is close to wavelength 550nm, and specifically becomes 0.3 in the green wavelength regions. This shows that 30% light will scatter. Due to this, it can be said that it is possible to realize a light diffusion layer that possesses wavelength selectivity for which it is possible to selectively scatter light for the green wavelength regions by suspending spherical copper particles of radius 49nm in a medium of refractive index 1.49.

[0128] Next, it is understood that the scattering rate of red wavelength region light is improving in comparison to other wavelength regions, as shown in Fig. 25, when an investigation is made into when this scattering layer is placed on the thin optical film (53) of the projector screen (51) in Example 1. According to this, it can be said that it is possible to improve the scattering properties in the green wavelength regions by placing the light diffusion layer described above on the thin optical film (53) of the projector screen (51) in Example 1, but the light diffusion layer that uses spherical gold particles as the metal micro particles is being applied for use in making supplementary micro adjustments without obtaining any significant improvement in scattering properties due to the absorption cross section being large when close to 550nm. Furthermore, the vertical axis in Fig. 25 shows the total of the scattering rate and the reflectance with the scattering rate.

[0129] [Example 7] In Example 7, an investigation was conducted into light diffusion layers that have spectral scattering properties by using spherical silver particles as metal micro particles and projector screens that possess these. First, the values for the real part *n* of the complex refractive index of silver, specifically the refractive index, and the imaginary part *k*, specifically the extinction coefficient, is as described in Example 4.

[0130] In Example 7, the light diffusion layer is constructed by suspending silver particles of radius 40nm, which is different from Example 4, in a medium with refractive index 1.6. This time, the scattering efficiency, excluding the scattering cross section by the projection area, is as in Fig. 26. The scattering efficiency was obtained through calculation of the Mie scattering using the complex refractive index for a single spherical silver particle. In Fig. 26, the vertical axis shows the scattering efficiency, specifically, that it is possible to scatter the projection area by several times. According to Fig. 26, it is understood that the scattering efficiency reaches maximum for wavelength 527nm.

[0131] Next, a scattering film was formed by suspending these spherical particles in the same medium for which the number density becomes qty. $3x10^{10}/cm^3$. The film thickness of the scattering film was assumed to be about 87μm. Then, we searched for the scattering coefficient when a scattering film formed in this manner underwent multiple scattering. The results are shown in Fig. 27. The vertical axis in Fig. 27 shows the scattering coefficient. As shown in Fig. 27, the scattering coefficient has a gradual peak, and the peak scattering coefficient is close to wavelength 530nm, and specifically becomes 0.2 in the green wavelength regions. This shows that 20% light will scatter. Due to this, it can be said that it is possible to realize a light diffusion layer that possesses wavelength selectivity for which it is possible to selectively scatter light for the green wavelength regions by suspending spherical copper particles of radius 40nm in a medium of refractive index 1.6.

[0132] Next, it is understood that the scattering rate of red wavelength region light is improving in comparison to other wavelength regions, as shown in Fig. 28, when an investigation is made into when this scattering layer is placed on the thin optical film (53) of the projector screen (51) in Example 1. According to this, it can be said that it is possible to improve the scattering properties in the green wavelength regions by placing the light diffusion layer described above on the thin optical film (53) of the projector screen (51) in Example 1, but in this case, a

significant improvement in scattering properties as in the case of Example 4 is not obtained, and it is being applied for use in making supplementary micro adjustments. Furthermore, the vertical axis in Fig. 28 shows the total of the scattering rate and the reflectance with the scattering rate.

[0133] [Example 8] In Example 8, an investigation was conducted into cases of having multiple scattering properties broader than in Example 7. Specifically, in Example 8, light diffusion layers having spectral scattering properties through use of spherical nickel particles as metal micro particles, and projector screens that possess these, were constructed. First, the real part *n* of the complex refractive index of nickel, specifically the refractive index, and the imaginary part *k*, specifically the value of the extinction coefficient, is shown in Fig. 29. The vertical axis in Fig. 29 shows the values for the real part *n* and the imaginary part *k*, while the horizontal axis shows the wavelength.

[0134] At this point, the scattering efficiency, excluding the scattering cross section by the projection area, when spherical nickel particles of radius 49nm are suspended in a medium of refractive index 1.6, becomes as in Fig. 30. The scattering efficiency was obtained through calculation of the Mie scattering using the complex refractive index. In Fig. 30, the vertical axis shows the scattering efficiency, specifically the possibility of multiple scattering of the projection area. As shown in Fig. 30, the scattering efficiency has a gradual curve that draws a large curve, and reaches maximum for wavelength 542nm.

[0135] Next, a scattering film was formed by suspending these spherical copper particles in the same medium for which the number density becomes qty. $8x10^9/cm^3$. The film thickness of the scattering film was assumed to be about 468μm. Then, we searched for the scattering coefficient when a scattering film formed in this manner underwent multiple scattering. The results are shown in Fig. 31. The vertical axis in Fig. 31 shows the scattering coefficient. As shown in Fig. 30, the scattering coefficient in cases of multiple scattering is different from cases with a single particle, and, as shown in Fig. 31, broad characteristics are shown, and the peak scattering coefficient is 0.1. This shows that 10% of light will scatter, and shows the scattering properties will be improved by about the same level for a wide wavelength region, from blue wavelength regions to red wavelength regions. Due to this, it can be said that it is possible to realize a light diffusion layer that possesses scattering properties for which is possible to scatter light for a wide wavelength region at about the same level, from blue wavelength regions to red wavelength regions, by suspending nickel particles with radius 49nm in a medium with refractive index 1.6.

[0136] Next, it is understood that the scattering rate of light for blue wavelength regions, green wavelength regions, and red wavelength regions is improving slightly in comparison to other wavelength regions, as in Fig. 32, when an investigation is made into when this scattering layer is placed on the thin optical film (53) of the projector screen (51) in Example 1. According to this, it can be said that it is possible to improve the scattering properties in the green wavelength regions by placing the light diffusion layer described above on the thin optical film (53) of the projector screen (51) in Example 1, but, in this case, it is being applied for use in making supplementary micro adjustments without obtaining any significant improvement in scattering properties. Furthermore, the vertical axis in Fig. 32 shows the total of the scattering rate and the reflectance with the scattering rate.

[0137] Furthermore, although an example in which images are displayed by projecting primarily narrow-band primary color wavelength region light was explained in the form of the implementation described above, projection screens with this invention are not limited to primary color wavelength region light for narrow bands, and it is possible to use light emitting elements such as a light emitting diodes, for example, as a light source which has a spread in the emission wavelength in comparison to such sources as a laser. It is acceptable even if it is one that splits the wavelength within the visible region, as with primary colors, by combining a light source for which the spread in the band is slight with a filter, nonlinear optical elements, or nonlinear thin optical film. Specifically, this invention is one that has a wide spread for the wavelength, and can be used with LED projectors that have a light source that is as narrow as this invention, and other types of projectors that generally use primary color wavelength region light. In addition, they can be effectively used with single color light sources.

[0138]

[Effects of Invention] Projection screens related to this invention are projection screens for displaying images by projecting narrow-band primary color wavelength region light, and possess a thin optical film on an insulator for support that has high transmittance characteristics with regards to the aforementioned narrow-band primary color wavelength region light, and are ones that possess a thin optical film on an insulator for support that has high transmittance properties with regards, at least, for visible wavelength light other than the particular wavelength region light.

[0139] With projection screens related to this invention constructed as above, narrow-band primary color wavelength region light is reflected, and most of the light for wavelengths other than this penetrates the thin optical film, due to possession of a thin optical film as mentioned above.

[0140] Accordingly, it is possible largely to control the reflection of outside light in comparison to conventional screens with this type of screen, and as a result, it is possible to obtain bright images, together with being able to effectively reduce the drop in contrast of images formed on the projection screen, and the reflection of outside light. Accordingly, it is possible to obtain clear images even in cases with a bright projection environment, and provide a clear image without any effect from the brightness of the projection environment, due to projection screens related to this invention.

[0141] In addition, these screens are ones which have high reflective properties with regards to fixed wavelength regions, are good even when constructed possessing a thin optical film on an insulator for support that has high reflective properties for at least visible wavelength light other than the particular wavelength region light, are ones for which light that has the same fixed wavelength regions is reflected for the main wavelength regions, and for which the light for other wavelength regions mostly penetrates the thin optical film. Accordingly, clear images are obtained even for light that has fixed wavelength regions, and through this invention, it becomes possible to provide clear images without any effects from the brightness of the projection environment.

[Simple Explanation of Diagrams]

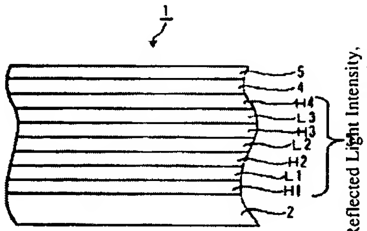
[Fig. 1] Cutaway diagram of a projection screen constructed according to this invention.

[Fig. 2] Characteristics drawing that shows the relationship of the scattering coefficient, and the reflection intensity and scattering intensity.
[Fig. 3] Outline block diagram explaining the construction of a diffraction grating-type projector device.
[Fig. 4] Conceptual diagram showing the conditions in which light incidences on GLV.
[Fig. 5] Conceptual diagram showing conditions for reflected light with GLV.
[Fig. 6] Top view showing example of a single construction for a GLV.
[Fig. 7] Cutaway diagram showing the construction of a projection screen related to Example 1.
[Fig. 8] Characteristics drawing showing transmittance characteristics of a projection screen related to Example 1.
[Fig. 9] Characteristics drawing showing the relationship between the optical thickness *nd* and the average transmittance.
[Fig. 10] Characteristics drawing showing transmittance characteristics for projection screens related to Example 2.
[Fig. 11] Characteristics drawing showing the ratio of the average transmittance of the residual transmittance and visible light band, and the refractive index.
[Fig. 12] Characteristics drawing showing the transmittance characteristics of a projection screen related to Example 3.
[Fig. 13] Characteristics drawing showing the complex refractive index for silver.
[Fig. 14] Characteristics drawing showing the scattering efficiency for a single spherical silver particle.
[Fig. 15] Characteristics drawing showing the relationship between the wavelength when spherical silver particles are multiply scattered and the scattering coefficient.
[Fig. 16] Characteristics drawing showing the total of the scattering rate and reflectance for a projector screen related to Example 4 with the scattering rate, and the relationship with the wavelength.
[Fig. 17] Characteristics drawing showing the complex refractive index for copper.
[Fig. 18] Characteristics drawing showing the scattering efficiency for a single spherical copper particle.
[Fig. 19] Characteristics drawing showing the relationship between the wavelength when spherical copper particles are multiply scattered and the scattering coefficient.
[Fig. 20] Characteristics drawing showing the total of the scattering rate and reflectance for a projector screen related to Example 5 with the scattering rate, and the relationship with the wavelength.
[Fig. 21] Characteristics drawing showing the scattering rate and reflectance of a projector screen constructed from layers of thin optical film related to Example 4 and thin optical film related to Example 5, with the total of the scattering rate, and the relationship with the wavelength.
[Fig. 22] Characteristics drawing showing the complex refractive index for gold.
[Fig. 23] Characteristics drawing showing the scattering efficiency for a single spherical gold particle.
[Fig. 24] Characteristics drawing showing the relationship between the wavelength when spherical gold particles are multiply scattered and the scattering coefficient.
[Fig. 25] Characteristics drawing showing the relationship between the total of the scattering rate for a projector screen related to Example 6 and the reflectance with the scattering rate, and the wavelength..
[Fig. 26] Characteristics drawing showing the scattering efficiency for a single silver particle.
[Fig. 27] Characteristics drawing the relationship between the wavelength and scattering rate when a spherical silver particle is multiply scattered.
[Fig. 28] Characteristics drawing showing the scattering rate and reflectance of a projector screen related to Example 7, with the total of the scattering rate, and the relationship with the wavelength.
[Fig. 29] Characteristics drawing showing the complex refractive index for nickel.
[Fig. 30] Characteristics drawing showing the scattering efficiency for a single spherical nickel particle.
[Fig. 31] Characteristics drawing showing the relationship between the wavelength and scattering coefficient when a spherical nickel particle is multiply scattered.
[Fig. 32] Characteristics drawing showing the scattering rate and reflectance for a projector screen related to Example 8, with the total for the scattering rate, and the relationship with the wavelength.

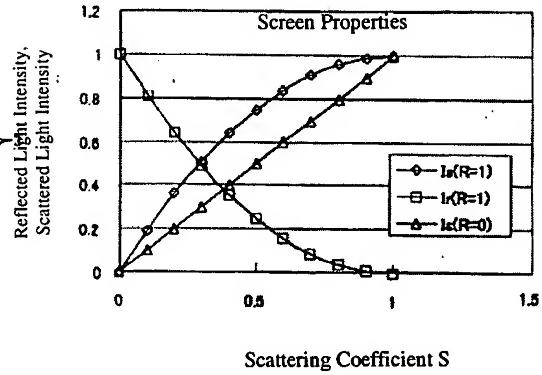
[Explanation of Marks]

1 Projector Screen
2 Screen Substrate
3 Thin Optical Film
4 Light Diffusion Layer
5 Protective Film

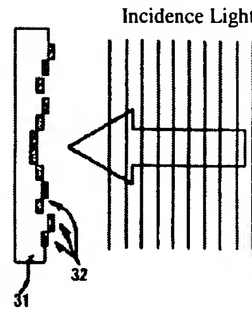
[Fig. 1]



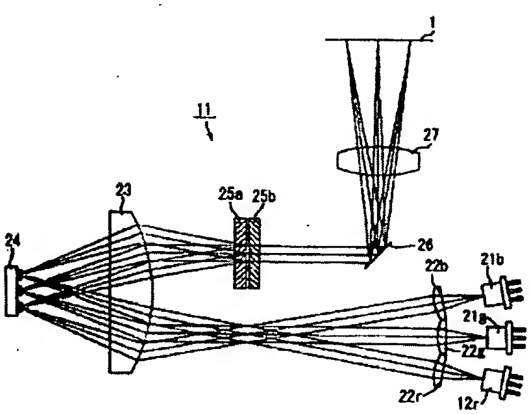
[Fig. 2]



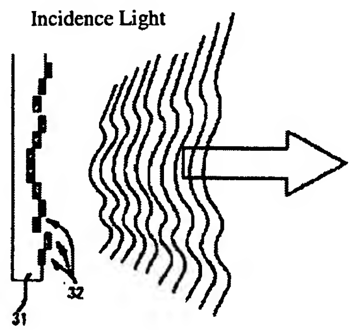
[Fig. 4]



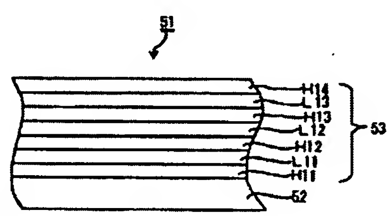
[Fig. 3]



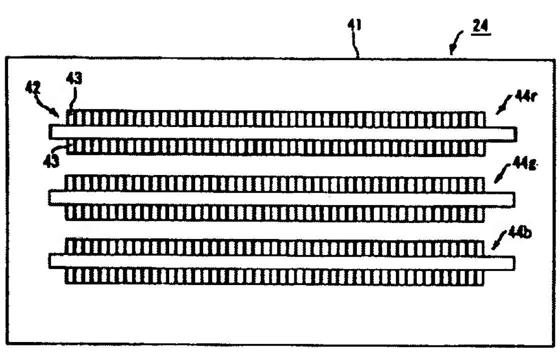
[Fig. 5]



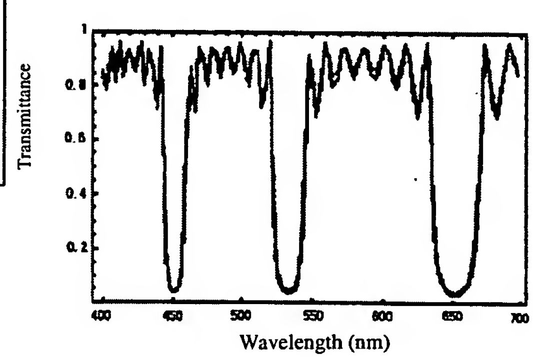
[Fig. 7]



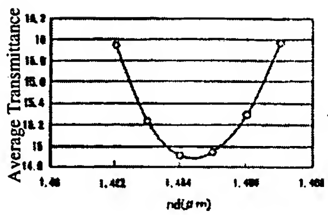
[Fig. 6]



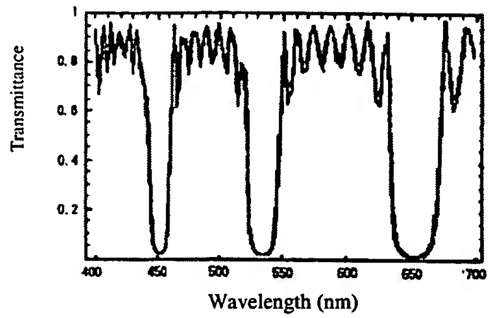
[Fig. 8]



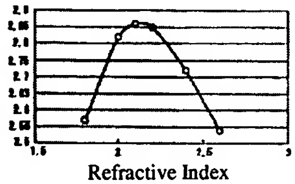
[Fig. 9]



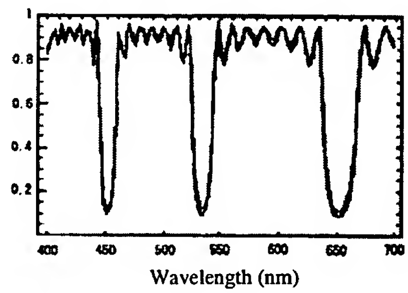
[Fig. 10]



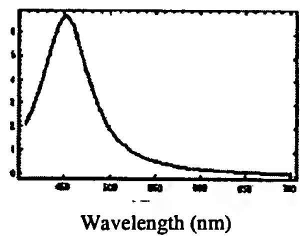
[Fig. 11]



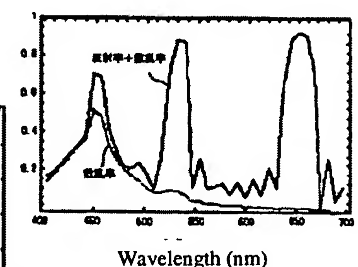
[Fig. 12]



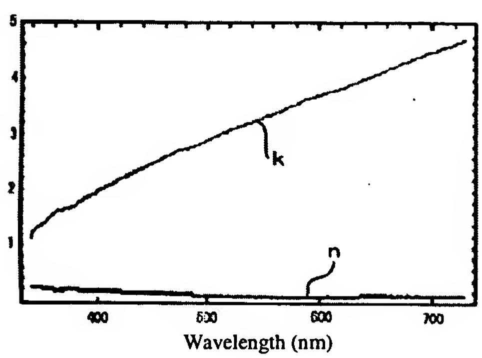
[Fig. 14]



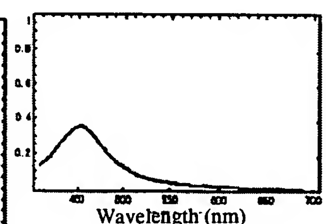
[Fig. 16]



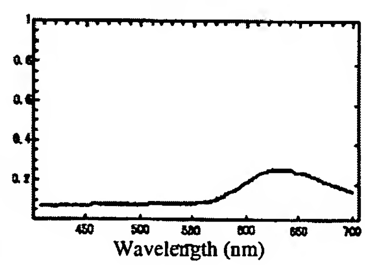
[Fig. 13]



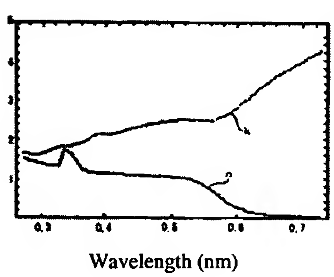
[Fig. 15]



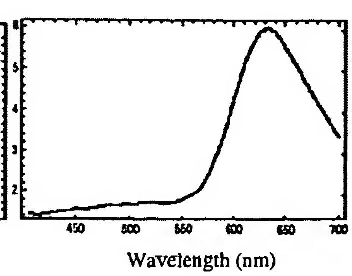
[Fig. 19]



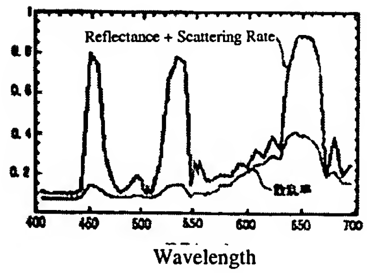
[Fig. 17]



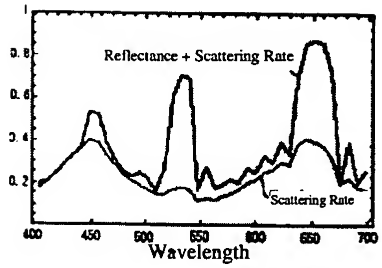
[Fig. 18]



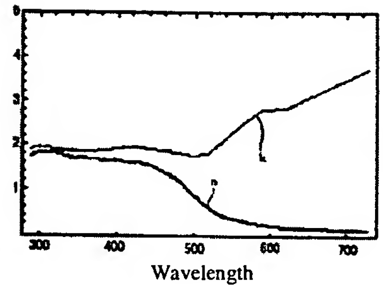
[Fig. 20]



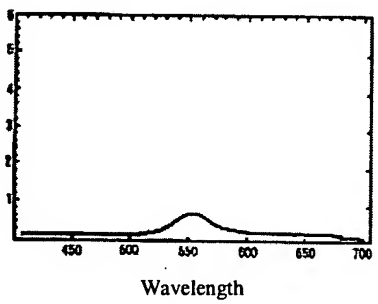
[Fig. 21]



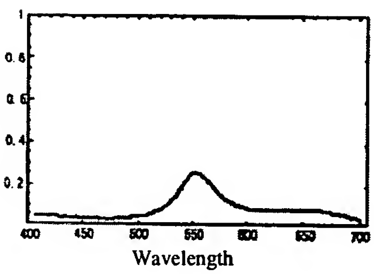
[Fig. 22]



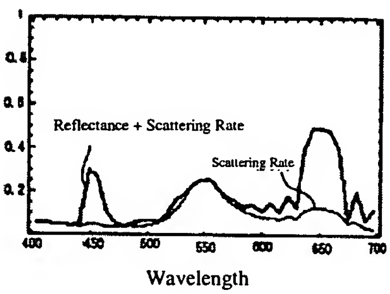
[Fig. 23]



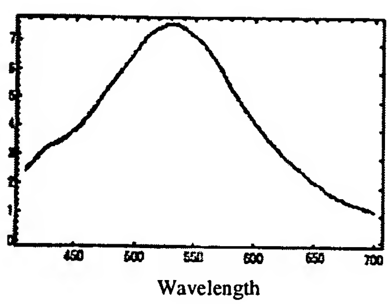
[Fig. 24]



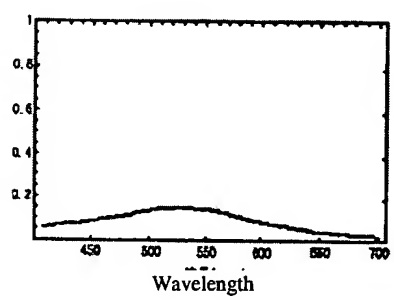
[Fig. 25]



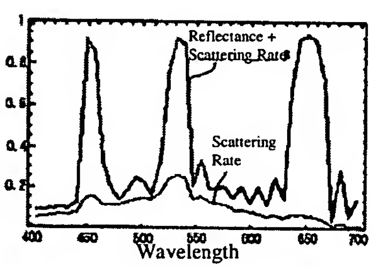
[Fig. 26]



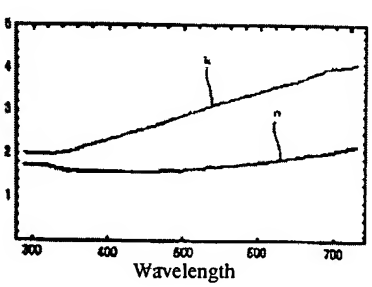
[Fig. 27]



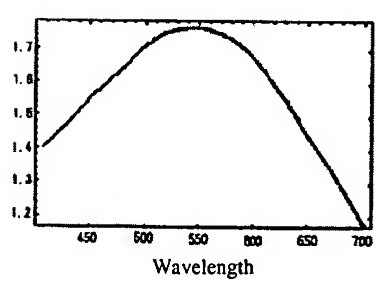
[Fig. 28]



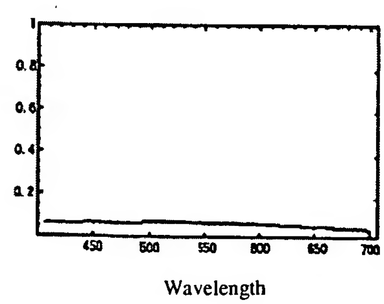
[Fig. 29]



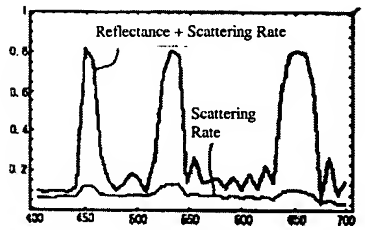
[Fig. 30]



[Fig. 31]



[Fig. 32]



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